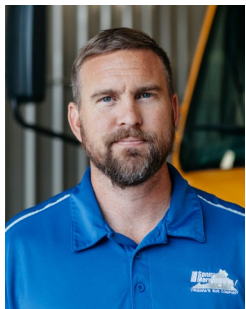


Jouley Electric School Bus First Responder Training



Daniel Droog
Sonny Merryman Trainer
ddroog@sonnymerryman.com



Jouley, the Electric School Bus



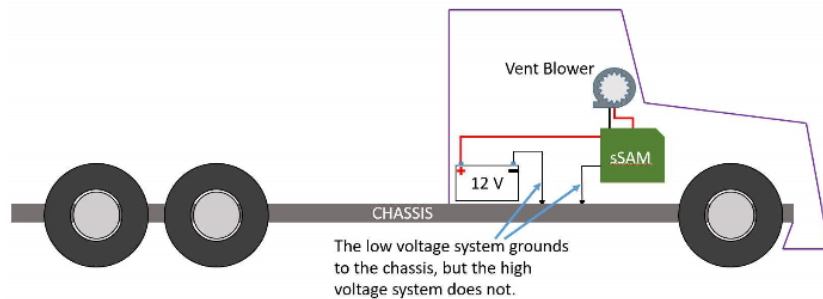
Vehicle:	Jouley School Bus – C2 Electric Bus
Power E-motor cont. :	120KW/161HP (Proterra)
Voltage level / energy content	400V, 220 kWh
Range:	134 miles (estimated range)

Identifying a Jouley Electric School Bus

1. Blue Thomas emblem beside passenger door
2. Blue Thomas emblem on front hood
3. Proterra logo on the front hood
4. Blue Thomas emblem on rear above bumper

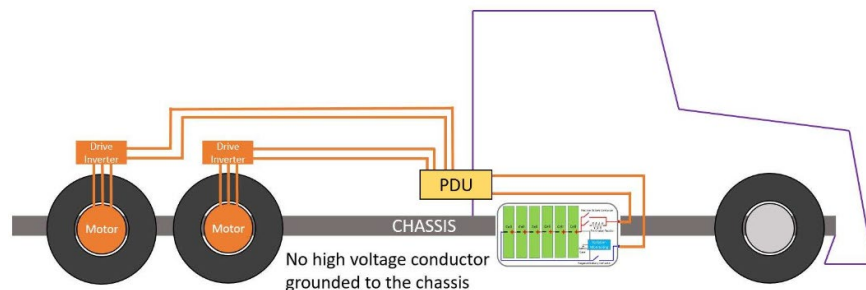


Separated High Voltage and Low Voltage Electrical Systems



Grounded Low Voltage System

We'll start with the familiar. Low voltage components often have the negative terminal of the component grounded to the cab or chassis. This makes a reliable, convenient connection point, and presents no safety hazard due to the low voltage involved.



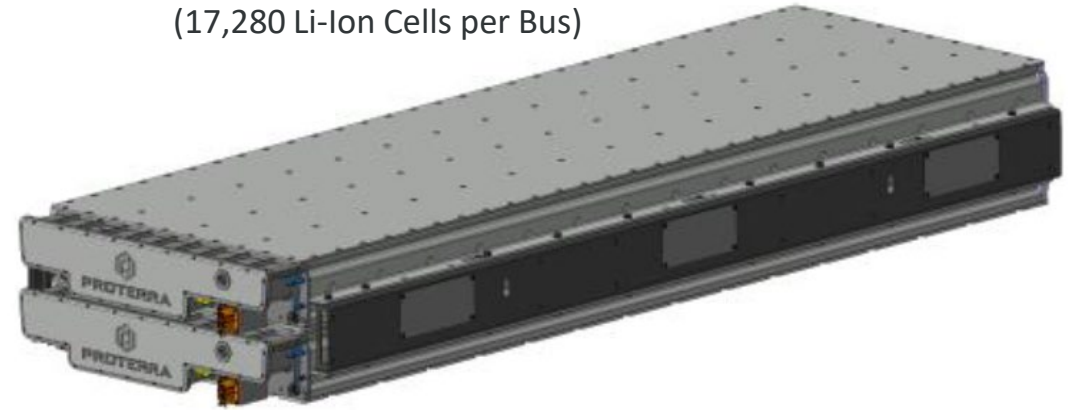
Separated High Voltage System

Although the outer metal cases of all high voltage components *are grounded* to the chassis, the high voltage electrical system itself is not. The benefit of this system is that no single fault or short circuit to chassis will cause a battery short circuit, or pose a dangerous shock hazard.

Two Proterra Battery Packs

There are two (2) battery packs powering the high voltage systems on the vehicle. They also maintain the low voltage 12-volt system through a DC to DC converter. The battery packs are cooled by an internal heat exchanger and are connected to an external heat exchanger and HVAC chill plates by a dedicated cooling loop. The battery packs contain vent to prevent pressure buildup within the packs. A Manual Service Disconnect (MSD) is located on the driver's side rearward end of each pack.

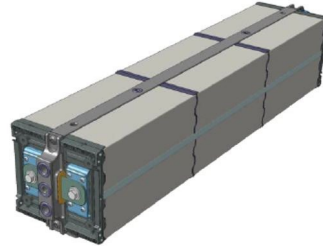
Dual Battery Pack Assembly
(17,280 Li-Ion Cells per Bus)



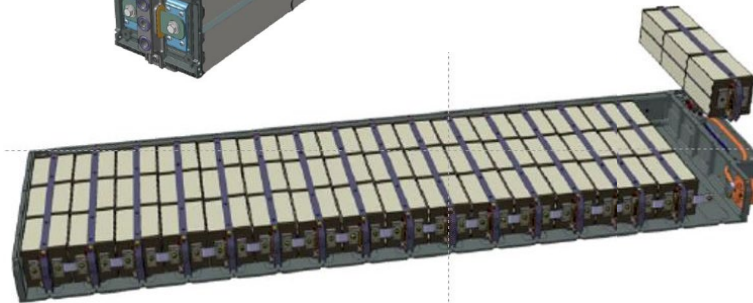
4.2 Volt Li-Ion Cells
12 Cells to a Cassette
(wired parallel)



4.2 Volt Li-Ion Brick
8 Cassettes to a Brick [96 Cells]
(wired parallel)



25.2 Volt Li-Ion Module
6 Bricks to a Module [576 Cells]
(wired in series)



378 Volt Li-Ion Pack
15 Modules to a Pack [8,640 Cells]
(wired in series)

How much voltage is *High Voltage*?

According to the DIN VDE 0100 Part 410 standard, electrical hazard for humans starts at 50 V of alternating current (AC) or 120 V of direct current (DC). The updated / released OSHA standard 1910.303(g)(2)(i) applies, and specifies that the maximum voltage that can be left unguarded/unshielded as **50 V AC or DC**.

High Voltage Component Labels

High voltage components are marked with this label. For safety, these components are constructed such that tools and deliberate action are required to access their internal workings.

According to OSHA, a hazard for humans starts at:

50 V alternating current (AC)
120 V direct current (DC)

OSHA 29 CFR 1910.303(g)(2)(i) /
NFPA 70E limit is **50V**, AC or DC.



3B. Hazards Associated with Mechanical Damage

Mechanical damage to Proterra battery packs can result in a number of hazardous conditions, including:

- Leaked battery pack coolant (See Section 3D)
- Leaked cell electrolyte (See Section 3E)
- Rapid heating of individual cells due to exothermic reaction of constituent materials (cell thermal runaway), venting of cells, and propagation of self-heating and thermal runaway reactions to neighboring cells.
- Fire

To prevent mechanical damage to Proterra battery packs, these items should be stored in their original packaging when not in use or prior to being installed.

3C. Hazards Associated with Elevated Temperature Exposure

The Proterra battery pack is designed to withstand operating temperatures up to 55°C and 95% non-condensing humidity.

- Storage for more than 24 hours at temperatures above 80°C could result in cell thermal runaway reactions and should be avoided.
- Storage for more than a few minutes at temperatures above approximately 150°C could result in cell thermal runaway reactions and should be avoided.
- Exposure of battery packs to localized heat sources such as flames could result in cell thermal runaway reactions and should be avoided.

3E. Hazards Associated with Leaked Electrolyte

The electrolyte within constituent cells includes a volatile hydrocarbon-based liquid and a dissolved lithium salt (which is a source of lithium ions) such as lithium hexafluorophosphate. The electrolyte is largely absorbed in electrodes within individual sealed cells. Under normal usage conditions battery electrolyte should not be encountered by anyone handling a Proterra battery pack.

Severe mechanical damaged (e.g. severe crushing) can cause a small quantity of electrolyte to leak out of a cell. For the electrolyte liquid to come into contact with an operator the battery pack enclosure and the cell would have to be mechanically damaged.

The possibility of a spill of electrolyte from a Proterra battery pack is very remote. Electrolyte can be extracted from a single cell using a centrifuge, or under some extreme abuse conditions such as a severe crush. However, it is very difficult to mechanically damage cells in such a way as to cause leakage of electrolyte. Even if a battery pack were damaged in a manner that could cause electrolyte leakage, it is extremely difficult to cause a leak from more than a few cells due to any incident.

Any released electrolyte liquid is likely to evaporate rapidly leaving a white salt residue. Evaporated electrolyte is flammable and will contain alkyl-carbonate compounds. Leaked electrolyte is colorless and characterized by a sweet odor. If an odor is obvious, evacuate or clear the surrounding area and ventilate the area. **WARNING: AVOID CONTACT WITH ELECTROLYTE.**

3E. Hazards Associated with Leaked Electrolyte (CONTINUED)

Leaked electrolyte solution is flammable and corrosive / irritating to the eyes and skin. If a liquid is observed that is suspected electrolyte, ventilate the area and avoid contact with the liquid until a positive identification can be made and sufficient protective equipment can be obtained (eye, skin, and respiratory protection). Chemical classifier strips can be used to identify the spilled liquid (electrolyte will contain petroleum/organic solvent and fluoride compounds).

In case of an electrolyte leak, the following protective equipment is recommended: an air purifying respirator with organic vapor/acid gas cartridges, safety goggles or a full face respirator, and safety gloves. Protective clothing should be worn. Use a dry absorbent material to clean up a spill.

3F. Hazards Associated with Vented Electrolyte

Lithium-ion cells are sealed units, and thus under normal usage conditions, venting of electrolyte should not occur. If subjected to abnormal heating or other abuse conditions, electrolyte and electrolyte decomposition products can vaporize and be vented from cells. Accumulation of liquid electrolyte is unlikely in the case of abnormal heating. Vented gases are a common early indicator of a thermal runaway reaction – an abnormal and hazardous condition.

If gases or smoke are observed escaping from a Proterra battery pack, evacuate the area and notify a first responder team and/or the local fire department. Gases or smoke exiting a Proterra battery pack are likely flammable and could ignite unexpectedly as the condition that led to cell venting may also cause ignition of the vent gases. A venting battery pack should only be approached with extreme caution by trained first responders equipped with appropriate personal protective equipment.

Cell vent gas composition will depend upon a number of factors, including cell composition, cell state of charge, and the cause of cell venting. Vent gases may include volatile organic compounds (such as alkyl-carbonates, methane, ethylene, and ethane), hydrogen gas, carbon dioxide, carbon monoxide, soot, and particulates containing oxides of nickel, aluminum, lithium, copper, and cobalt. Additionally, phosphorus pentafluoride, POF₃ and HF vapors may form. Vented gases are expected to be lighter than air.

WARNING: AVOID CONTACT WITH VENTED GASES. Vented gases may irritate the eyes, skin, and throat. Cell vent gases are typically hot: upon exit from a cell, vent gas temperatures can exceed 600°C. Contact with hot gases can cause thermal burns. Vented electrolyte is flammable, and may ignite on contact with a competent ignition source such as an open flame, spark, or a sufficiently heated surface. Vented electrolyte may also ignite on contact with cells undergoing a thermal runaway reaction.

4. First Aid Measures

Electric Shock / Electrocutation: Seek immediate medical assistance if an electrical shock or electrocution has occurred (or is suspected).

Contact with Leaked Electrolyte: The constituent battery cells are sealed. Contents of an open (broken) constituent battery cell can cause skin irritation and/or chemical burns. If materials from a ruptured or otherwise damaged cell or battery contact skin, flush immediately with water and wash affected area with soap and water. If a chemical burn occurs or if irritation persists, seek medical assistance.

For eye contact, flush with significant amounts of water for 15 minutes without rubbing and see physician at once.

Inhalation of Electrolyte Vapors: If inhalation of electrolyte vapors occurs, move person into fresh air. If not breathing give artificial respiration. Consult a physician.

Vent Gas Inhalation: The constituent battery cells are sealed and venting of cells should not occur during normal use. If inhalation of vent gases occurs, move person into fresh air. If not breathing give artificial respiration. Consult a physician.

5. Firefighting Measures

Smoke emanating from a Proterra battery pack is an indication of an abnormal and hazardous condition. The smoke is likely flammable and may ignite at any time. If fire or smoke is observed emanating from a battery pack at any time, evacuate the area, and notify appropriately trained first responders and the local fire department.

A trained first responder team or the local fire department should shut off power to the battery pack to prevent charging of the battery. However, shutting off power to the battery pack does not deenergize it, and thus a shock hazard may still be present. The battery pack should then be monitored for evidence of continued smoke evolution. Application of high volumes of water from a safe distance to cool the battery pack may prevent further reaction and prevent a fire from developing.

If a fire develops, the Incident Commander should determine whether an attempt will be made to suppress the fire (aggressive firefighting) or allow the battery pack to burn until it self-extinguishes, while protecting surrounding materials (defensive firefighting).

Virtually all fires involving lithium-ion batteries can be controlled with water. To date, water has been found to be the most effective agent for controlling lithium-ion battery fires. Water will suppress flames and can cool cells, limiting propagation of thermal runaway reactions. If water is used, electrolysis of water (splitting of water into hydrogen and oxygen) may contribute to the flammable gas mixture formed by venting cells, burning plastic, and burning of other combustibles. Thus copious volumes of water should be used to fight a lithium-ion battery fire.

Gaseous agents such as CO₂ or Halon, or dry chemical suppressants may temporarily suppress flaming of lithium-ion battery packs, but they will not cool lithium-ion batteries and will not limit the propagation of cell thermal runaway reactions. Metal fire suppressants such as LITH-X, graphite powder, or copper powder are not appropriate agents for suppressing fires involving lithium-ion battery packs as they are unlikely to be effective.

A battery fire may continue for several hours and it may take 24 hours or longer for the battery pack to cool. A lithium-ion battery fire that has been extinguished can re-ignite due to the exothermic reaction of constituent materials from broken or damaged cells. To avoid this, remove sources of ignition and cool the burned mass by flooding with water.






5. Firefighting Measures (CONTINUED)

Aggressive Firefighting: If a decision is made to aggressively fight a fire involving a Proterra battery pack, then copious amounts of water should be applied from a safe distance. The water may not suppress all cell thermal runaway reactions within the battery pack, but it may cool cells and control the spread of the fire. If possible, direct the application of water towards openings in the battery pack enclosure, if any have formed, with the intent of flooding the pack enclosure. The objective is to contact the surfaces of the affected and surrounding individual battery cells with water.

Defensive Firefighting: If a decision is made to fight a Proterra battery pack fire defensively, then the fire crew should pull back a safe distance and allow the battery to burn itself out. Fire crews may choose to utilize a water stream or fog pattern to protect exposures or control the path of smoke. A battery fire may continue for several hours and may result in multiple re-ignition events. It may take 24 hours or longer for the battery pack to cool.

Firefighter PPE: Firefighters should wear self-contained breathing apparatus (SCBA) and fire protective turnout gear. Cells or batteries may flame or leak potentially hazardous organic vapors if exposed to excessive heat, fire or over voltage conditions. These vapors may include volatile organic compounds (VOCs), hydrogen gas, carbon dioxide, carbon monoxide, soot, and particulates containing oxides of nickel, aluminum, lithium, copper, and cobalt. Additionally, phosphorus pentafluoride, POF₃ and HF vapors may form.

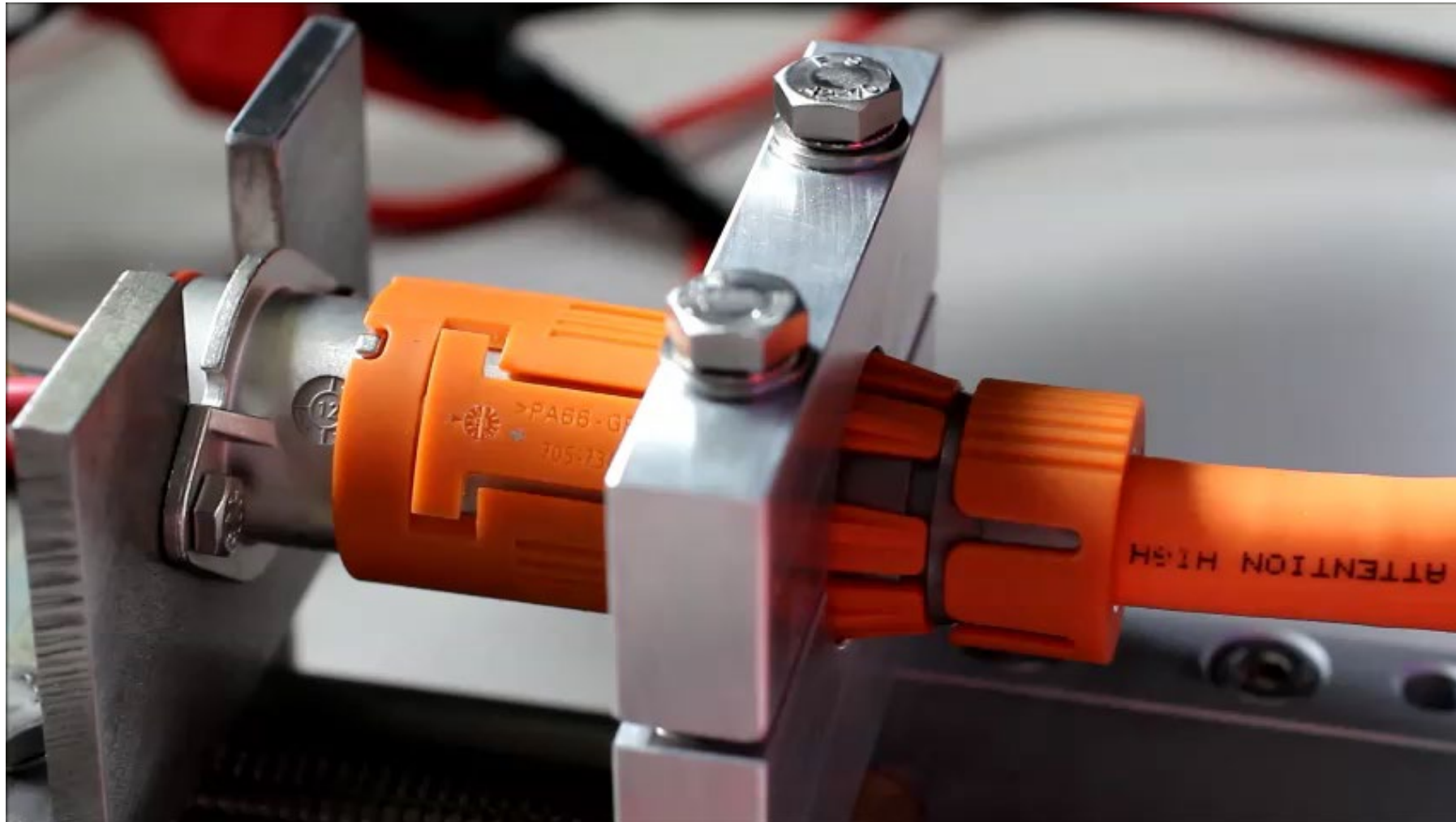
13. Identification elements (warning signs etc.)

	<p>Dangerous electric voltage: Shock hazard. General warning.</p>
	<p>Read instructions.</p>
	<p>Lifting point identification</p>
	<p>Battery pack warranty label</p>
	<p>High voltage warning</p>

14. Additional information

To the best of our knowledge the information in this product data sheet corresponds to what was known at the time of the creation and revision of this document. The information in this product data sheet is provided voluntarily by the manufacturer. It shall be taken as a reference for the safe handling of the product during use, storage, transport and recycling. Provided information from this product safety data sheet is not transferable to other products from Proterra, Inc. In case the product named in this product data sheet is combined, mixed or converted or subjected to processing, the information in this product data sheet shall not be transferred to the newly produced material. The current product data sheet for Proterra HV battery pack can be obtained from Proterra, Inc.

Arc Flash Demonstration

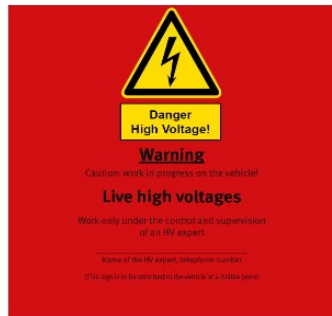


Arc Flash Demonstration



Safety by Organization

When working on a high voltage vehicle, access to these high voltage systems is restricted to personnel that are properly trained and are performing maintenance or repair.



When the high voltage sign is posted at the vehicle, there is a possibility of contacting live high voltages. Do not enter the Limited Approach Boundary.



When this sign is posted on the vehicle, it is safely locked-out and tagged-out. You may work on this vehicle under supervision of the SH in charge.



A lock properly installed on an eCascadia's emergency stop switch.

Personal Protective Equipment (PPE)

In addition to the PPE that is normally worn in a shop environment, PPE that protects the wearer against high voltage contact or arc flash must also be worn when appropriate.



Behavior-Related Measure

High voltage work must be conducted by trained personnel according to approved, risk-assessed work instructions.

Insulating Glove Classes

- Class 00 — Maximum use voltage of 500 volts AC/proof tested to 2,500 volts AC and 10,000 volts DC
- ✓ Class 0 — Maximum use voltage of 1,000 volts AC/proof tested to 5,000 volts AC and 20,000 volts DC
- Class 1 — Maximum use voltage of 7,500 volts AC/proof tested to 10,000 volts AC and 40,000 volts DC
- Class 2 — Maximum use voltage of 17,000 volts AC/proof tested to 20,000 volts AC and 50,000 volts DC
- Class 3 — Maximum use voltage of 26,500 volts AC/proof tested to 30,000 volts AC and 60,000 volts DC
- Class 4 — Maximum use voltage of 36,000 volts AC/proof tested to 40,000 volts AC and 70,000 volts DC

Glove Inspections

- Gloves must be put into service within one year from the date that they were last electrically tested. (Indicated by the date stamp) If they sit on the shelf for over a year, they must be reinspected before using.
- After being placed in service, they must be inspected again within 6 months in order to continue using them.
- Some users don't want to have to keep track of service dates on multiple pairs of gloves, so they just go by the date stamp, even though they might sacrifice a few weeks or months.
- In Europe, gloves are not reinspected, but are simply discarded. In the United States, gloves can be sent to testing facilities, which will recertify and place a new date stamp on gloves. E.g. Magid Glove (<https://www.magidglove.com/electrical-glove-testing-egt.aspx>)
- Gloves must generally be worn with leather overglove for protection. However, if it is impossible to get enough dexterity with both layers, the rubber gloves can be worn alone. When doing so, you must wear one protection class higher than would otherwise be required, and the gloves must be electrically inspected (recertified) immediately after.

High Voltage Safety Software

Primary Function

- Prevent energizing the HV system until all the necessary signals are valid

Application

- Provide a signal to de-energize the HV circuit when a necessary CAN signal from a critical component is invalid
- The system shall inhibit re-energizing the HV circuit until a necessary CAN signal from a critical component is valid

High Voltage Component Labels

High voltage components are marked with this label. For safety, these components are constructed such that tools and deliberate action are required to access their internal workings.

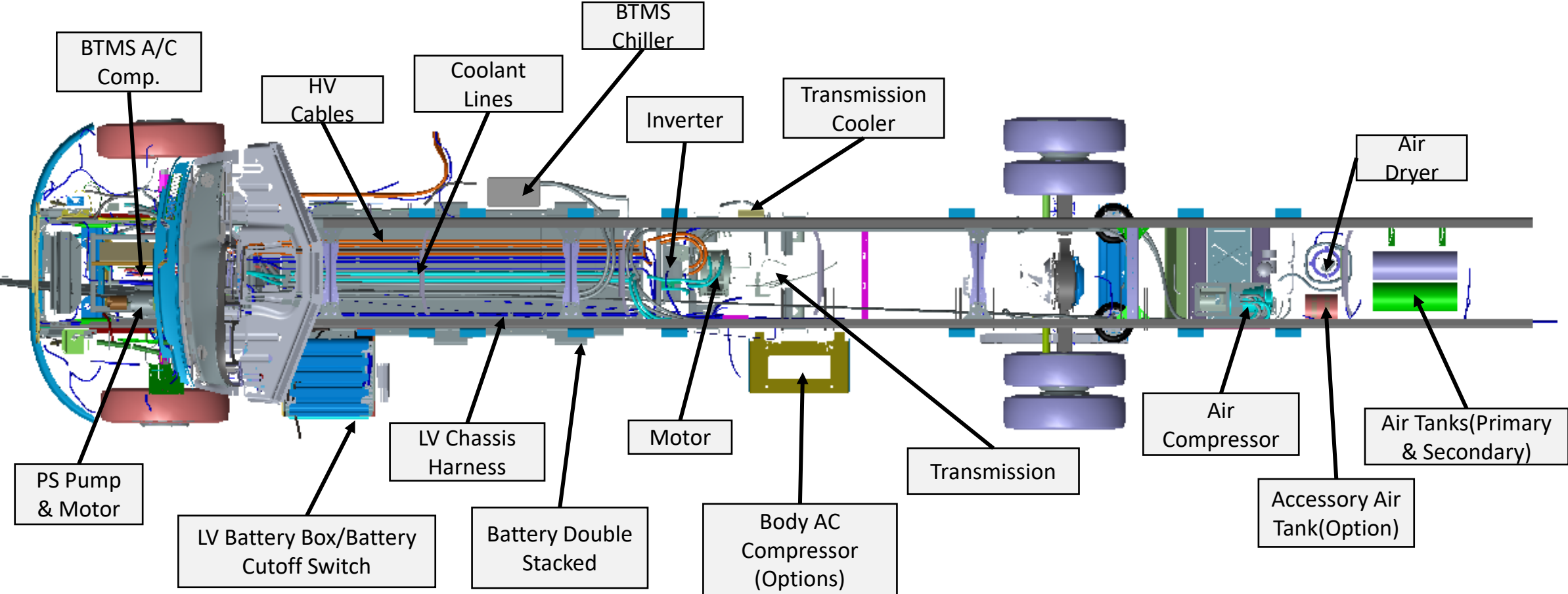


Touch-Safe Connectors and HVIL Pins

Male High voltage terminals are tipped with a plastic boot to prevent contact if HV system was active.



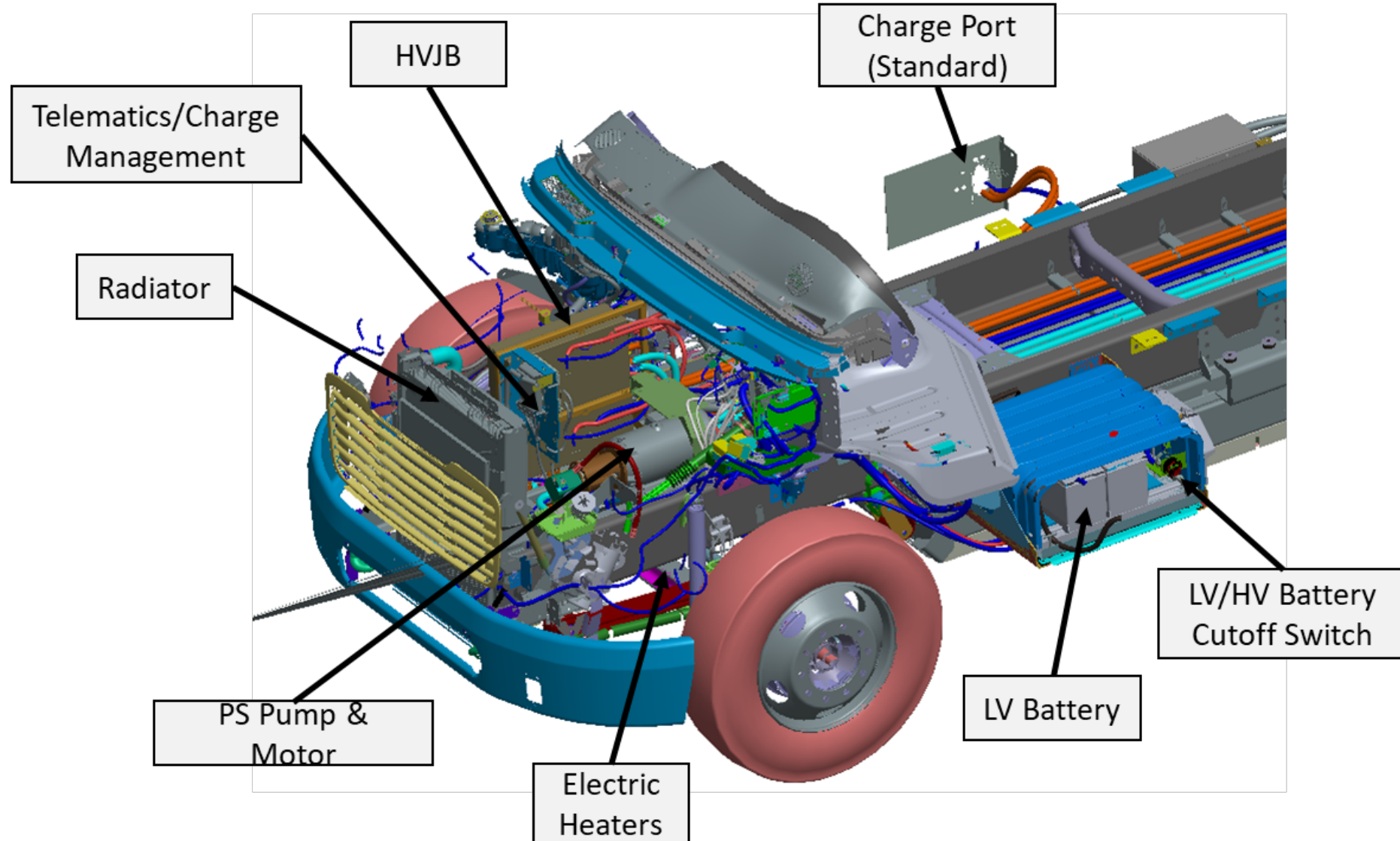
High Voltage Components



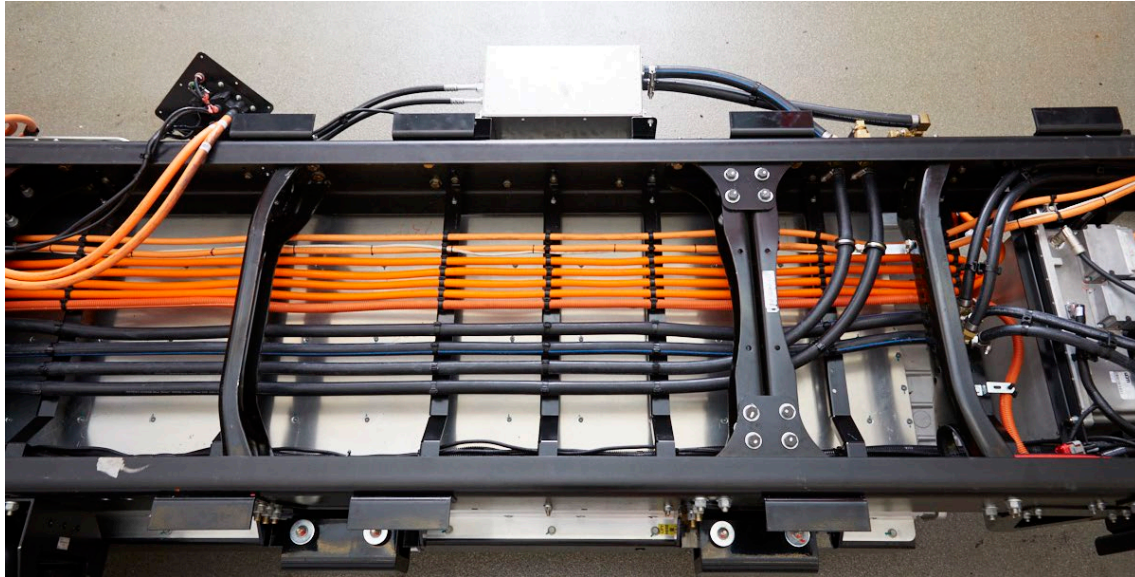
Jouley Chassis Layout

High Voltage Components

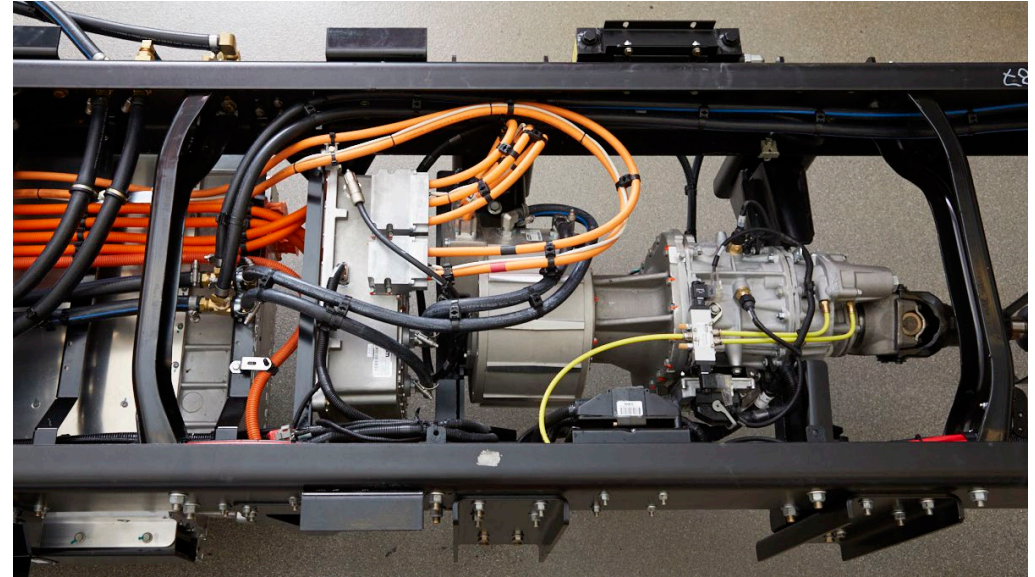
Jouley Front Compartment Layout



HV Cables & Coolant Hoses



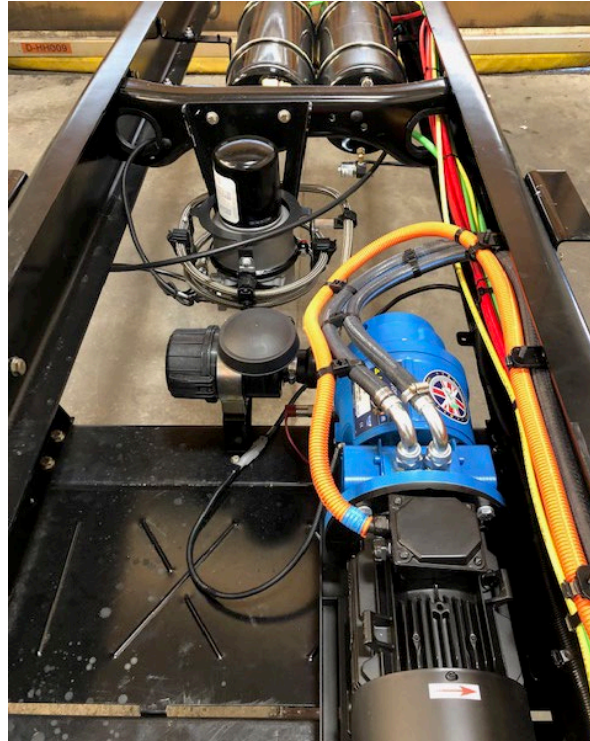
Inverter, Drive Motor & Transmission



BTMS A/C Comp.



Air Comp & Air Dryer



Electric Heaters





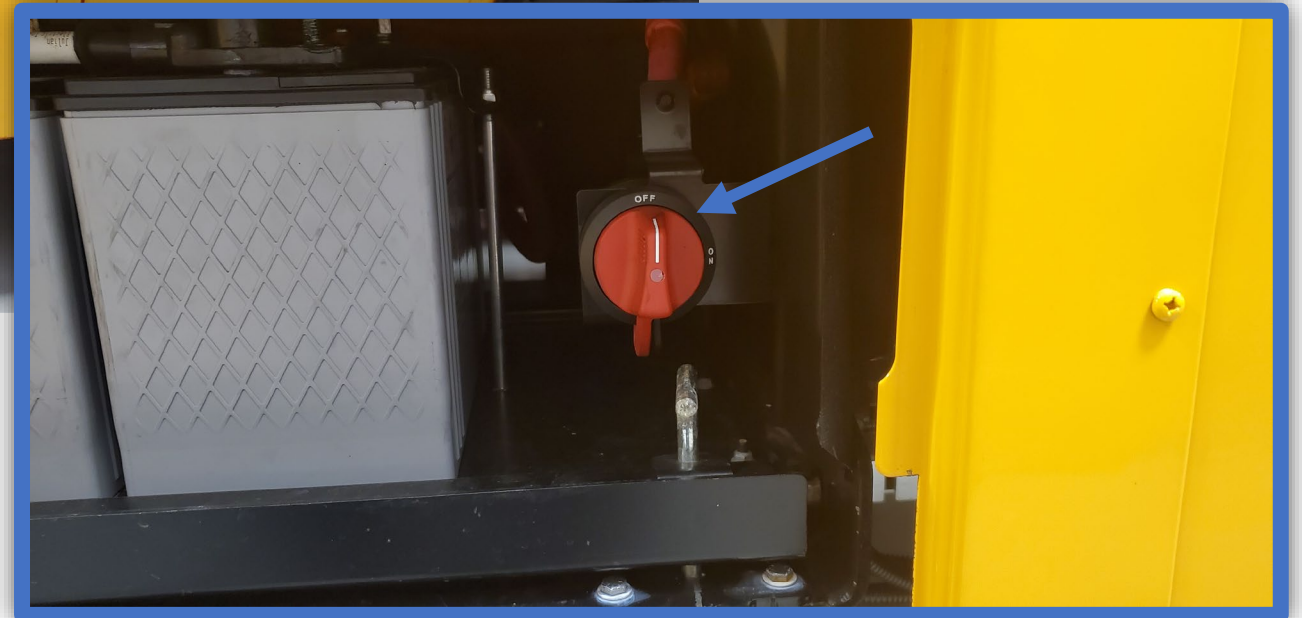
Key Off

With ignition key in the off position, the high voltage power is shut off.

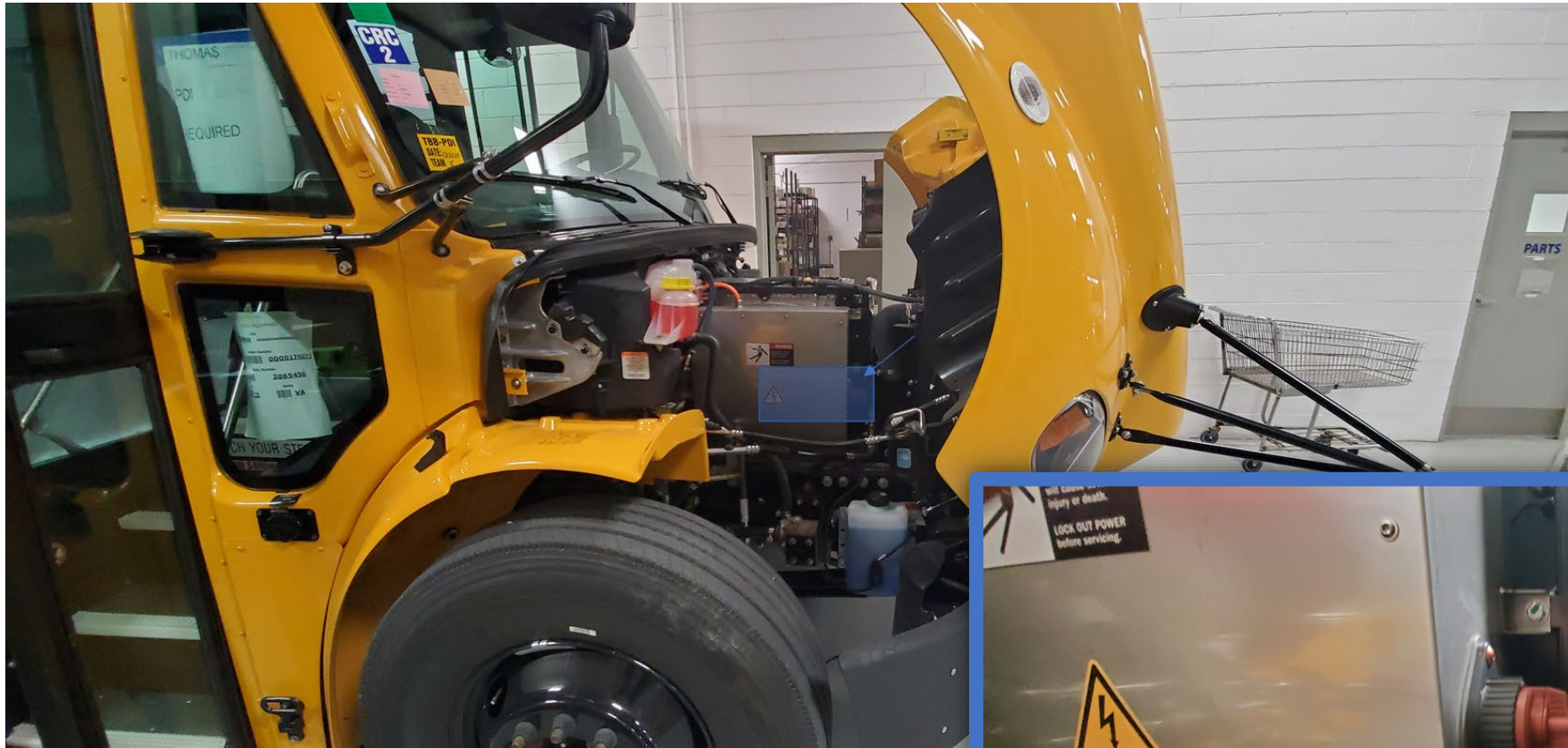
Powering Down the High Voltage System



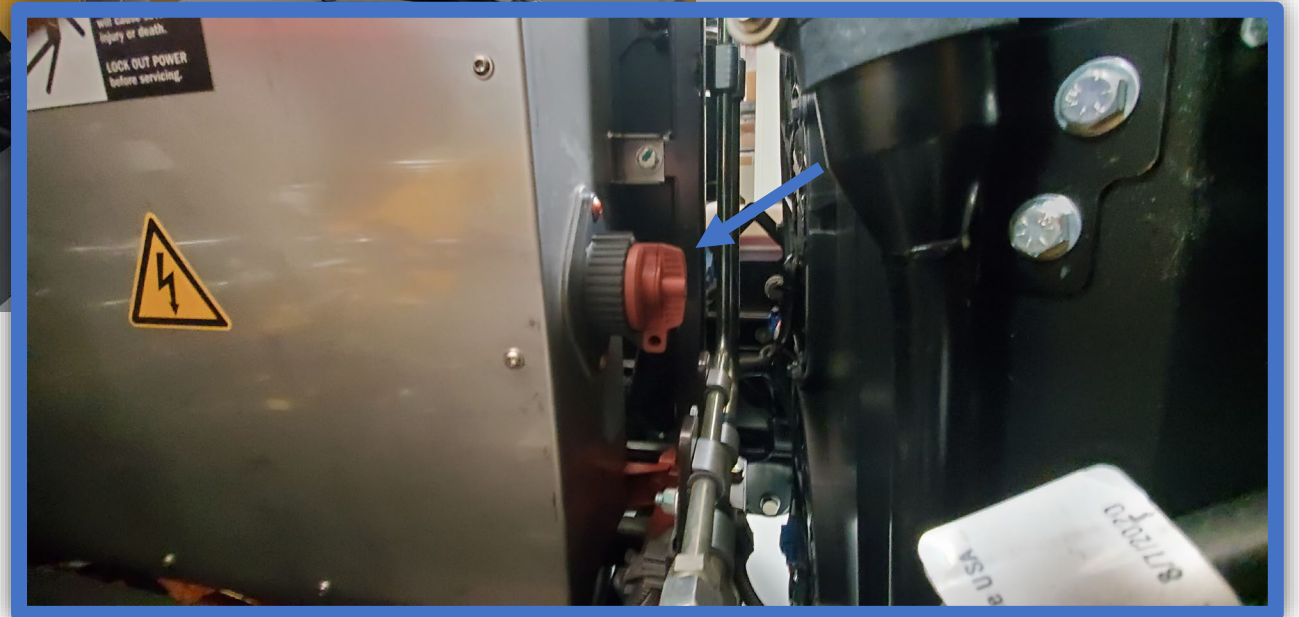
12V Battery Disconnect Switch



Powering Down the High Voltage System



High Voltage Junction Box Switch



Powering Down the High Voltage System

Manual Service Disconnect (MSD)

A manual service disconnect (MSD) is located on each of the two Proterra battery packs. The MSD disconnects the battery and stops any voltage or current from leaving the battery pack.

Proper PPE must be worn when removing the MSD due to the potential of arc flash.

Dual Battery Pack Assembly
(17,280 Li-Ion Cells per Bus)

